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Harvey

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(54) SELF-POWERED ELECTRONIC LOCK

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(52) **U.S. Cl.** **340/5.21**; 340/5.2; 340/5.7; 340/5.61; 340/5.63; 70/277; 235/382

(58) **Field of Classification Search** 340/5.2, 340/5.7, 5.61, 5.63, 5.8, 5.21; 70/277, 278.1, 70/278.2, 278.3; 235/382
See application file for complete search history.

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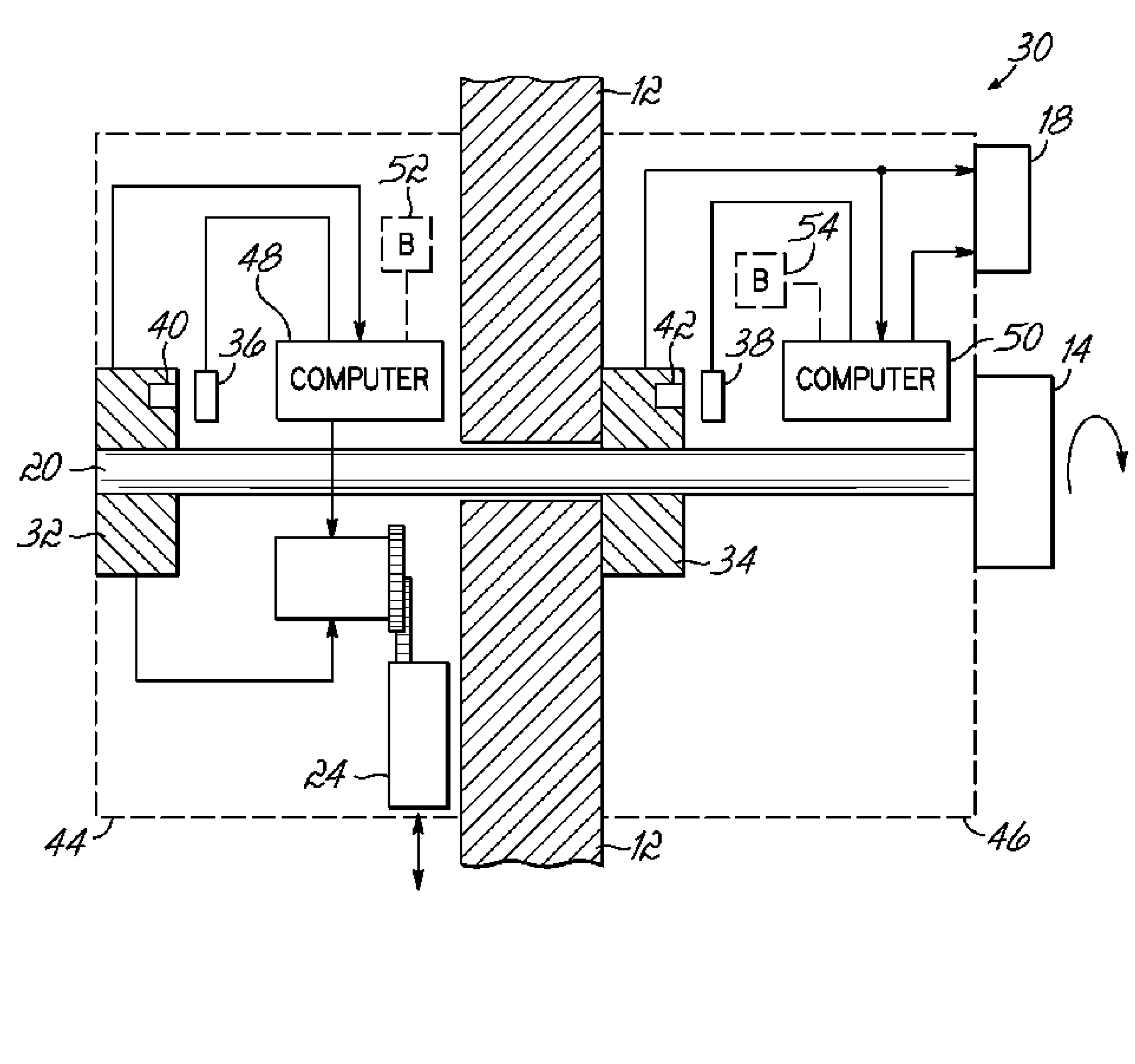
(57) **ABSTRACT**

A self-powered electronic lock is provided having a housing, a lock element mounted in the housing for movement relative to the housing between a locked position and an unlocked position, a code input device operating with a first set of electronics, and an electric actuator operating with a second set of electronics. The electric actuator is operatively coupled with the lock element to allow movement of the lock element from the locked position to the unlocked position. A first electric power generator is operative by a user to supply electrical power for operating the code input device and the first set of electronics. A second electric power generator is operative to supply electrical power for operating the electric actuator and the second set of electronics. The first and the second set of electronics are electrically isolated and are synchronized to generate a common number for a combination code.

26 Claims, 6 Drawing Sheets



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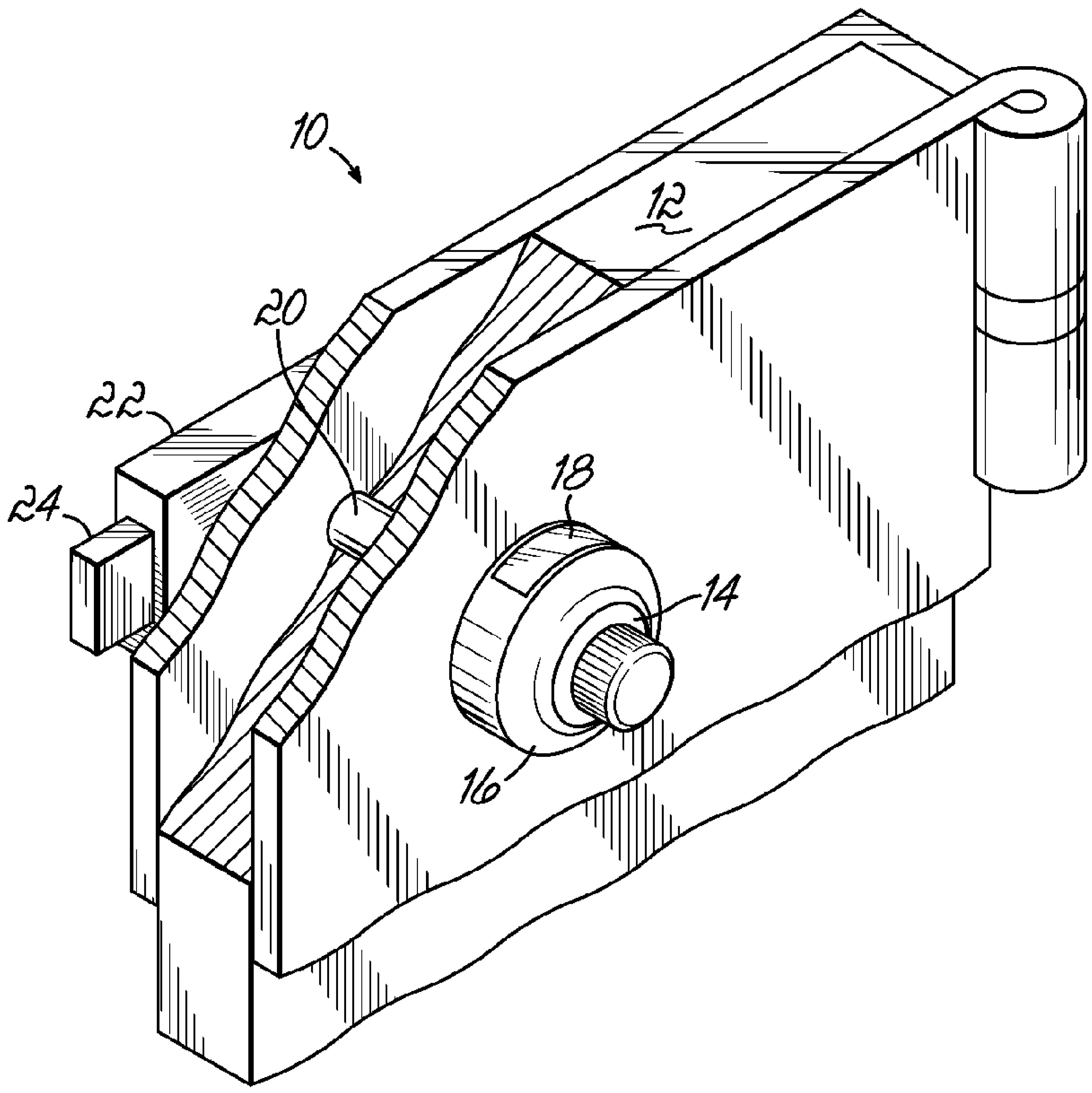

10
12
20
22
24
18
14
16

FIG. 1

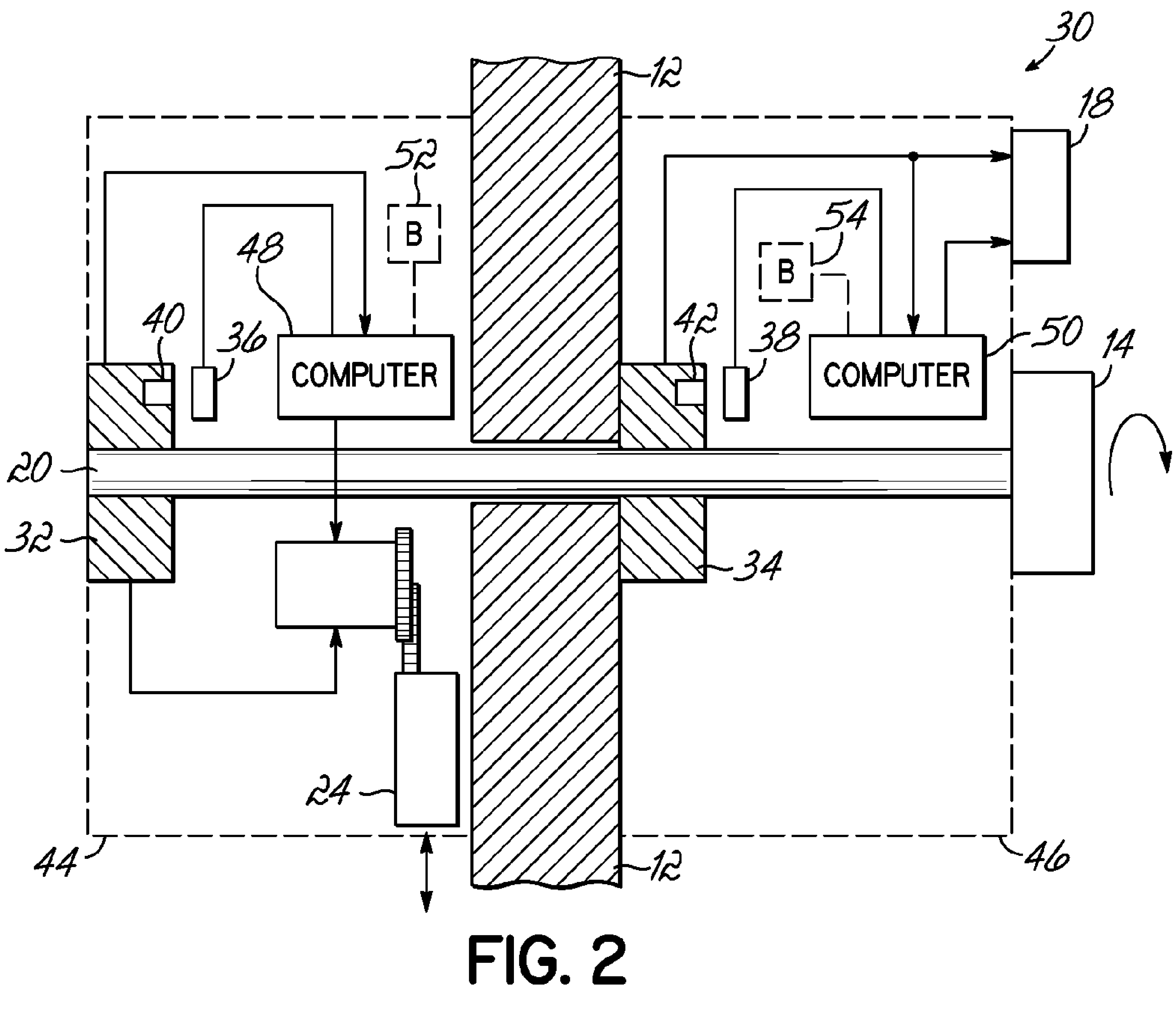

30
12
18
52
B
48
54
B
40
36
COMPUTER
42
38
COMPUTER
50
14
20
32
34
24
44
12
46

FIG. 2

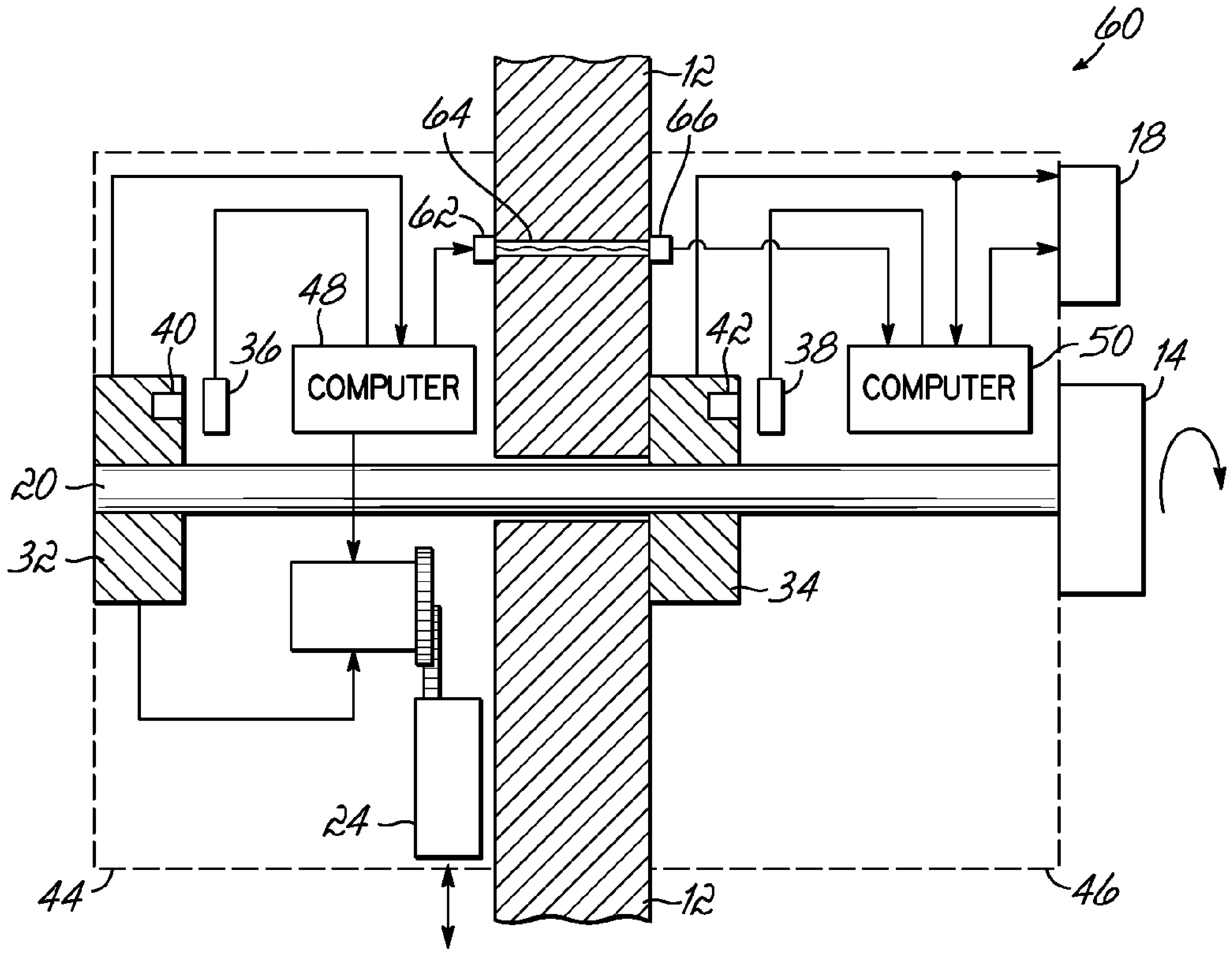

60
12
64
66
18
62
48
40
36
42
38
50
14
COMPUTER
COMPUTER
20
32
34
24
44
46
12

FIG. 3

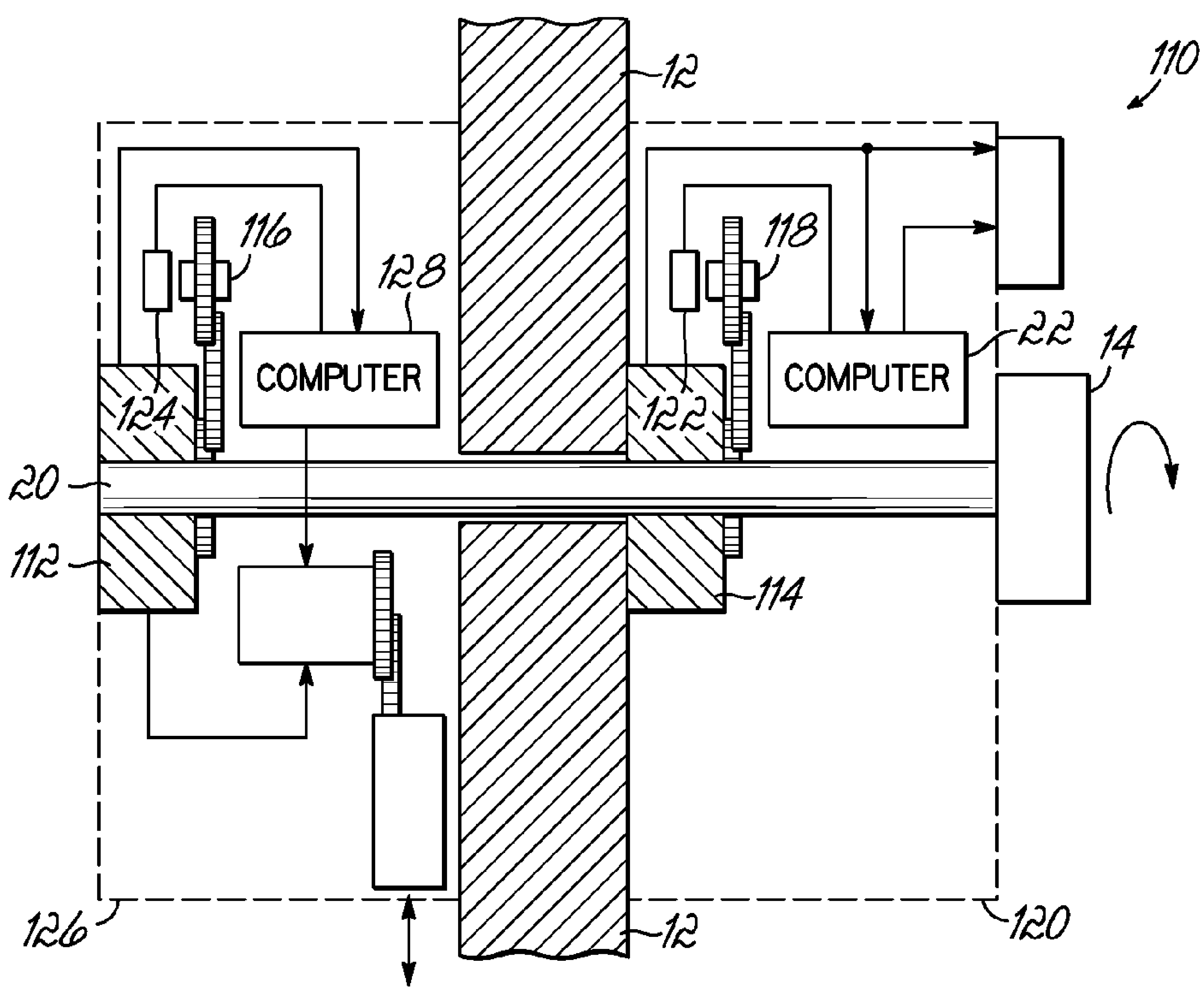

110
12
116
128
118
22
14
COMPUTER
COMPUTER
124
122
20
112
114
126
120
12

FIG. 5

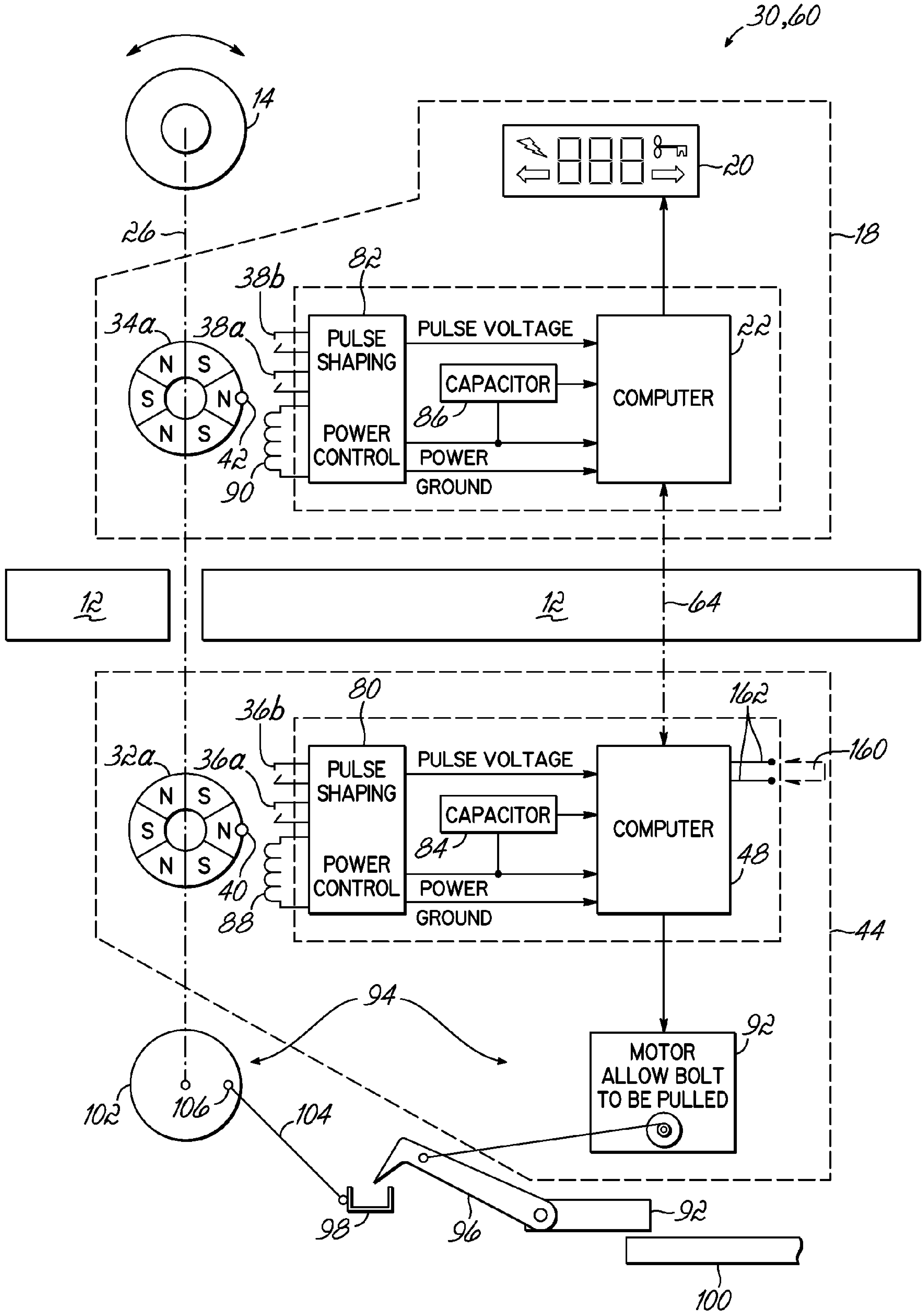

30,60
14
20
26
18
82
38b
34a
38a
PULSE SHAPING
PULSE VOLTAGE
22
CAPACITOR
COMPUTER
86
POWER CONTROL
POWER
42
90
GROUND
12
12
64
80
36b
162
32a
36a
PULSE SHAPING
PULSE VOLTAGE
160
CAPACITOR
COMPUTER
84
48
POWER CONTROL
POWER
40
88
GROUND
44
94
92
MOTOR ALLOW BOLT TO BE PULLED
102
106
104
98
96
92
100

FIG. 4

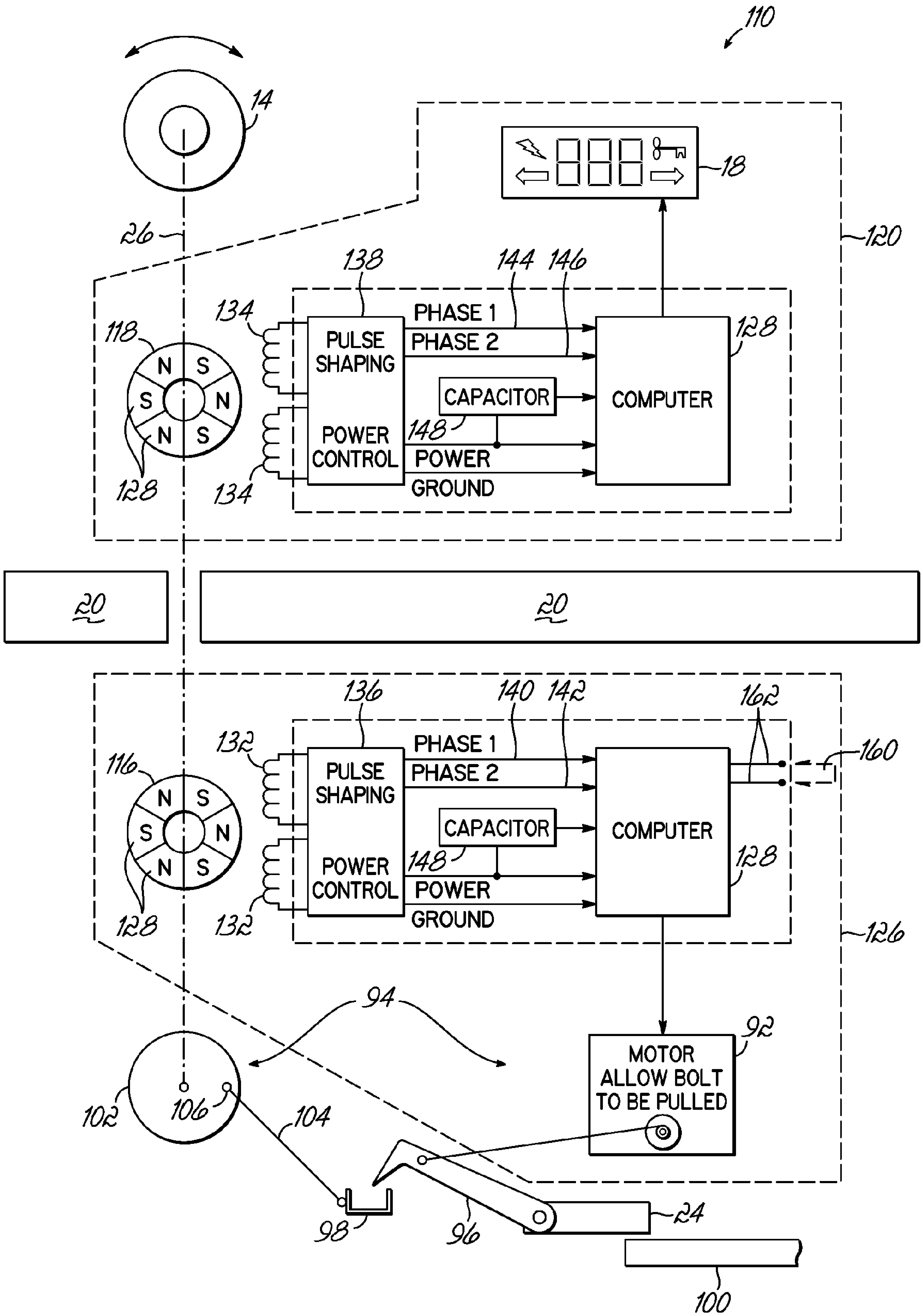
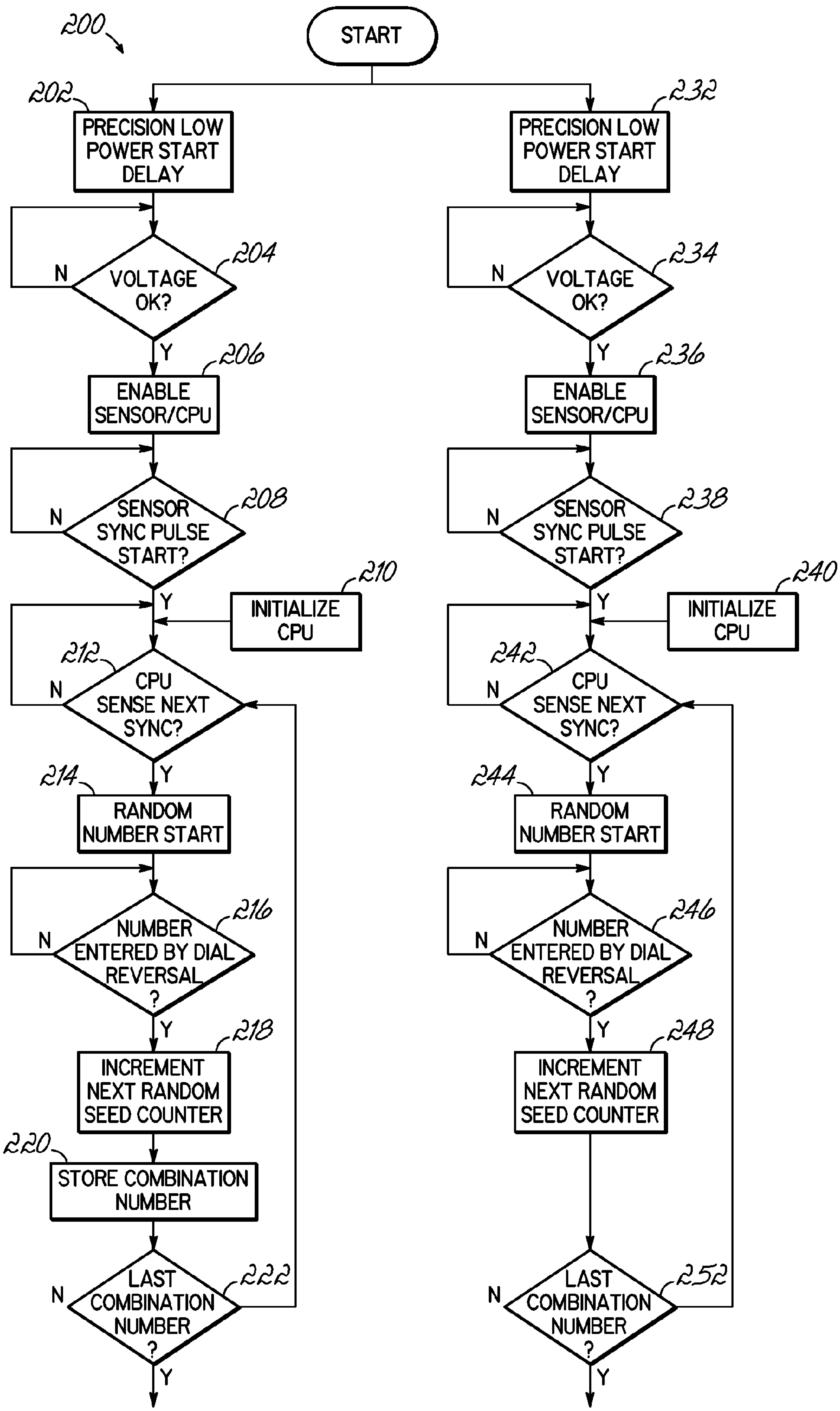

110
14
18
26
120
138
144
146
134
PHASE 1
PHASE 2
118
PULSE SHAPING
128
N S S N N S
CAPACITOR
COMPUTER
148
POWER CONTROL
POWER
128
134
GROUND
20
20
136
140
142
162
132
PHASE 1
160
116
PULSE SHAPING
PHASE 2
N S S N N S
CAPACITOR
COMPUTER
148
128
POWER CONTROL
POWER
128
132
GROUND
126
94
92
MOTOR ALLOW BOLT TO BE PULLED
102
106
104
24
98
96
100

FIG. 6



200
START
202
PRECISION LOW POWER START DELAY
204
VOLTAGE OK?
N
Y
206
ENABLE SENSOR/CPU
208
SENSOR SYNC PULSE START?
N
Y
210
INITIALIZE CPU
212
CPU SENSE NEXT SYNC?
N
Y
214
RANDOM NUMBER START
216
NUMBER ENTERED BY DIAL REVERSAL ?
N
Y
218
INCREMENT NEXT RANDOM SEED COUNTER
220
STORE COMBINATION NUMBER
222
LAST COMBINATION NUMBER ?
N
Y
232
PRECISION LOW POWER START DELAY
234
VOLTAGE OK?
N
Y
236
ENABLE SENSOR/CPU
238
SENSOR SYNC PULSE START?
N
Y
240
INITIALIZE CPU
242
CPU SENSE NEXT SYNC?
N
Y
244
RANDOM NUMBER START
246
NUMBER ENTERED BY DIAL REVERSAL ?
N
Y
248
INCREMENT NEXT RANDOM SEED COUNTER
252
LAST COMBINATION NUMBER ?
N
Y

FIG. 7

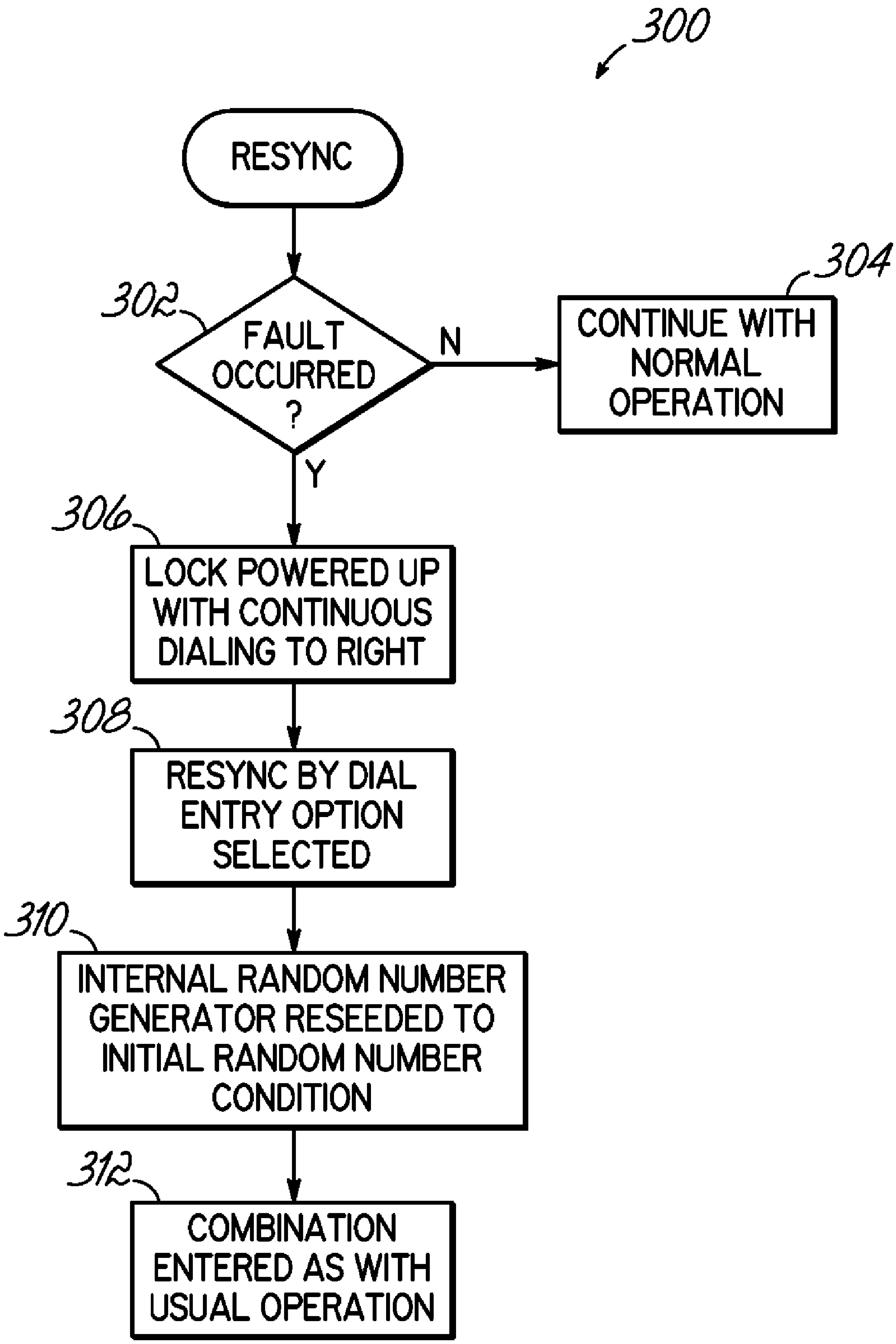

300
RESYNC
302
FAULT OCCURRED ?
N
Y
304
CONTINUE WITH NORMAL OPERATION
306
LOCK POWERED UP WITH CONTINUOUS DIALING TO RIGHT
308
RESYNC BY DIAL ENTRY OPTION SELECTED
310
INTERNAL RANDOM NUMBER GENERATOR RESEEDED TO INITIAL RANDOM NUMBER CONDITION
312
COMBINATION ENTERED AS WITH USUAL OPERATION

FIG. 8

SELF-POWERED ELECTRONIC LOCK

FIELD OF THE INVENTION

The present invention relates to locks, and more particularly to self-powered electronic locks.

BACKGROUND OF THE INVENTION

Self-powered locks have been known for some time. Self-powered locks are generally of two types. In the first type, movement of a member such as a knob or a handle provides power to the lock. Entry of the combination is accomplished by, for example, a key or card carrying a code or another code input device. The generation of power is separate from the code entry device.

The other type of such self-powered lock is exemplified by the lock disclosed in U.S. Pat. No. 5,061,923 issued to Miller et al., the disclosure of which is incorporated by reference herein in its entirety. In this type of lock, the same mechanism is used for generation of power for the lock and for the creation of electronic pulses. This type of lock has a permanently engaged drive from a dial to a stepper motor, which outputs voltage pulses in both directions of rotation and provides the same pulses to the microprocessor for purposes of controlling the lock, and in some configurations, for entering the combination.

In general, it is necessary to maintain the desired combination(s) within electronics interior to a safe container, behind a secured door, or in another inaccessible location. The number and status display, by necessity, must be located on the exterior and accessible to the operator of the lock. This has caused self-powered locks to be designed with electrical conductors connected between the outside electronics and the power generation device, which is generally located with the interior electronics. This connection method has proven cost effective in the past, but has caused some challenges during installation and some issues with reliability if the electrical conductors between the interior and exterior electronics become twisted or separated from the interior or exterior electronics.

SUMMARY

Embodiments of the invention provide a self-powered electronic lock including a housing, a lock element, and a code input device. The code input device is accessible to a user and operates with a first set of electronics. The lock element is mounted in the housing and moves relative to the housing between a locked position and an unlocked position. An electric actuator operates with a second set of electronics and is operatively coupled with the lock element to allow movement of the lock element from the locked position to the unlocked position. A first electric power generator supplies electrical power to the first set of electronics and for operating the code input device, while a second electric power generator supplies electrical power to the second set of electronics and for operating the electric actuator. Both the first and second electric power generators are operable by the user. The first and second set of electronics are electrically isolated and are synchronized to generate a common number for a combination code.

In one embodiment, a wireless communication device is configured to allow wireless communication between the first and second sets of electronics in order to transmit non-combination information and to synchronize the first and second set of electronics. The wireless communication methods may include any wireless communications such as communications via Bluetooth® technology, communications via general radio frequency communications, communications via pulsed magnetic fields, communications via pulsed electric fields, or communications via infrared signals, among others.

In some embodiments of the self-powered electronic lock, the second electric power generator and the second set of electronics are located inside the housing. This housing may be an internal housing that is not accessible to the user. Embodiments of the self-powered electronic lock may also include an external housing, which is adapted to be accessible to the user when the lock element is in the locked or unlocked position. The first electric power generator and the first set of electronics may be located inside the external housing. The internal and external housings may also be adapted to be disposed on opposite sides of an intervening structure.

The code input device may be located proximate to or coupled with the external housing to be accessible to the user. The code input device may be any type of device operable to provide a unique code to the self-powered electronic lock such as a dial, a keypad, a card reader, a radio frequency tag, a fingerprint scanner, a retinal scanner, or other biometric devices. Embodiments of the self-powered electronic lock may also include a display, which is electrically coupled to the code input device and powered by the first electric power generator. The display is operable to display a code input to the code input device by the user. Like the code input device, the display may be located proximate to or coupled with the external housing to also be accessible to the user.

In some embodiments of the self-powered electronic lock, the lock includes a rotatable shaft and a dial. The dial may be coupled to the first electric power generator through the rotatable shaft such that rotating the dial transfers a rotational motion to the first electric power generator through the shaft to generate electrical power. Similarly, the dial may additionally be coupled to the second electric power generator through the rotatable shaft such that rotating the dial simultaneously transfers the rotational motion to the first and second electric power generators through the shaft to generate electrical power. In addition to generating power, the dial may also operate as the code input device.

In some embodiments, the internal and external electronics are synchronized through the first and second power generators through the rotation of the shaft. The first and second power generators of the self-powered electronic lock for some embodiments may include stepper motors configured to generate pulses of electrical power. Other embodiments may utilize ring magnets with coils and Hall sensors. Synchronization between the first and second electronics may be established by generating synchronized pulses of electrical power by rotating the dial coupled to the shaft and the first and second power generators, then simultaneously transforming the synchronized pulses of electrical power into corresponding numbers using the first and second sets of electronics.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the detailed description given below, serve to explain the principles of the invention.

FIG. **1** shows a perspective view of an exemplary electronic lock illustrating an embodiment of the invention.

FIG. **2** is block diagram representing the components of an embodiment of the electronic lock in FIG. **1**.

FIG. **3** is block diagram representing the components of an alternate embodiment of the electronic lock in FIG. **2**.

FIG. **4** is another block diagram representing the components of the electronic lock in FIGS. **2-3**.

FIG. **5** is block diagram representing the components of an alternate embodiment of the electronic lock in FIG. **1**.

FIG. **6** is another block diagram representing the components of the electronic lock in FIG. **5**.

FIG. **7** is a flow chart of an exemplary power up and dial sequence of the electronic lock in FIG. **1**.

FIG. **8** is a flow chart of an exemplary resynchronization process of the electronic lock in FIG. **1**.

DETAILED DESCRIPTION

Embodiments of the invention provide a new configuration for an electronic lock having the external electronics separated from the internal electronics, without a need to have a wired electrical connection therebetween. Some embodiments may utilize wireless communications between the internal and external electronics, where the internal electronics may wirelessly transmit an opening status or a change key operation to the external electronics. Separate internal and external generators are utilized to power the internal and external electronics respectively. The internal electronics maintain the desired combination code and bolt retraction mechanism, retaining the security of the enclosure. The external electronics may drive an electronic display and may be synchronized with random number generation algorithms residing in the internal electronics. In the embodiments utilizing wireless communications, no combination information would be transmitted between the internal and external electronics over the wireless communications. In an embodiment with a minimum configuration, there will be no need for either power or data to be transmitted between the electronics in the lock.

Referring now to the drawings where like numbers reference like features, generally and in an embodiment of the self-powered electronic lock **10**, FIG. **1** shows the lock **10** mounted on a safe or vault door **12**. The lock **10**, in other embodiments, may also be located on a wall or other surface near the door **12** of the enclosure or room to be secured by the self-powered electronic lock **10**. A dial **14** may be surrounded by an external housing **16**, such as a dial ring, which shrouds the periphery of the dial **14** and the external electronics (**46** in FIG. **2**). In some embodiments, the external electronics may also include a display **18**. In some embodiments, the external housing **16** supports the display **18**. In other embodiments, the display **18** may be mounted separately from the dial **14**. The display **18** may be a Liquid Crystal Display (LCD) module, or any other low power consumption display device including a randomly initiated mechanical dial indicator. The dial **14** is attached to a shaft **20**, which may also be coupled to the external generator (**34** in FIG. **2**) such that the rotation of the shaft **20** by the dial **14** causes the external generator to generate power. In some embodiments, the shaft may extend out of the back of the external housing **16**, through a wall or door **12** of the enclosure to be secured and into the internal housing **22**. In other embodiments, offset shafts may be used that are mechanically linked to one another such that rotation of one shaft would cause the rotation one or more shafts. The internal housing **22** contains the internal electronics (**44** in FIG. **2**), which track the combination numbers entered on the lock and determine if a valid combination code has been entered. The internal electronics are powered by an internal generator (**32** in FIG. **2**), which is also coupled to the shaft **20** such that rotation of the dial **14** also causes the internal generator to generate power.

A lock element **24**, such as a bolt, may extend from the internal housing **22**, and may be used to secure the door **12** when extended. Mechanical linkages and mechanisms (**94** in FIGS. **4** and **6**) may also be contained in the internal housing **22**, which retract or extend the lock element **24** of the self-powered electronic lock **10**.

In an embodiment of the self-powered electronic lock **30**, pulses from the internal generator **32** and external generator **34** are utilized to indicate motion of the dial. Synchronization transducers **36**, **38**, indicate a specific, single, rotary position, and direction of movement. The synchronization transducers **36**, **38** may be implemented using a variety of technologies like optical, infrared, or magnetic. The use of magnets **40**, **42**, generally does not require offset gearing and may be less costly to implement.

In some embodiments, the synchronization of the correspondence between the code displayed and internal number is maintained with a method using common random number generators in the internal electronics **44** and the external electronics **46**. Generally, the existing random number seeds within a computer **48** in the internal electronics **44** and a computer **50** in the external electronics would be incremented only after a legitimate input number has been entered. In the case of a dial input, the dial **14** would be paused at the desired number, and then upon reversal of the dial the number would be accepted by the computer **48**. The computer **50** would not retain this number input. The computer **50** would only record the fact that an acceptable code had been entered, incrementing its random number kernel for the next number to be displayed.

In an alternate embodiment of the lock shown in FIG. **2**, optional small "keep alive" batteries **52**, **54** may be used to reduce the number of turns of the dial necessary to power the electronics, such as computers **48** and **50**. In this particular embodiment the batteries charge capacitors through a large resistor (not shown), though other electrical configurations could also be used, such as using the batteries to keep the computers **48**, **50** in a sleep mode. The storage capacitors are not gated on to the computers **48**, **50** until additional power input is supplied from the generators **32**, **34**. The stored energy in the capacitors allows for a quicker start of the electronics in the lock, potentially requiring only one or two half turns to start lock operation. The internal and external generators **32**, **34**, however, are still be used to provide lock power and pull the bolt. In the event either or both of the batteries **52**, **54** fail, the lock would operate as set forth in the embodiment above, where all of the power is supplied from the generators **32**, **34** and the rotation of the dial **14**.

In an embodiment of the self-powered electronic lock **60** with wireless transmission **62-66**, the external electronics **46** could be instructed when to increment the random kernel, and when to increment or decrement the displayed number. A wireless transmitter **62** sends wireless signals **64** to a wireless receiver **66**. In some embodiments, the transmitter **62** and receiver **66** may be transceivers capable of bi-directional communication. At no time, however, would the internal electronics **44** send the actual code to be displayed by the external electronics **46**. The computer **48** in the internal electronics **44** would only transmit an instruction to change the random number kernel, and possibly provide other instructions and/or information to be displayed. This additional information may include, but is not limited to incrementing or decrementing the display, indicating lock change key in operation, reporting total openings and total opening attempts, etc. Wireless communications may utilize RF communications, Bluetooth® communications, pulsed magnetic or electric fields, infrared signals or any other forms of wireless transmission.

In some wireless embodiments, the external electronics **46** may not require encoder technology such as the external generator **34**, transducer **38**, and magnet **42**. Instead, transmissions may be sent from the internal electronics **44** indicating a number change, though the actual number would still be maintained in the computer **50** and not transmitted from the computer **48**. In other wireless embodiments having the encoder electronics maintained in the external electronics **46**, the internal electronics **44** would not require the encoding electronics such as the internal generator **32**, transducer **36**, and magnet **40**. In this case, the external electronics with the encoder electronics would communicate to the internal electronics the appropriate information. However, at no time would the external electronics retain the actual opening combination.

For the embodiments in FIGS. **2**-**4**, the synchronization pulse area is located to be collinear with one of the magnetic ring poles and need only be as precise as the magnetic detents, because the dial always detents at one of the pole locations. The detents for this embodiment may be positioned as 1 in 50 around the dial, with one detent being the synchronization or "index" position. The index position is established by placing a small magnet **40**, **42** in coincidence with a magnetic pole of a ring magnet **32***a*, **34***a*, and simple magnetic closure electronics can then be used to indicate both the index position and a direction of rotation. The synchronization pulses are received via contact closures, which may be Hall effect transducers **36**, **38** or reed switches. The direction of the dial movement as well as the index point are determined as the combination is being entered. Because, the pulses alternate in polarity for any continuous directional rotation, any instantaneous direction change may be detected from the sequences of data pulses. Any two consecutive pulses of the same polarity indicate a direction change.

In some embodiments of the dual generator lock, it may be necessary to define the inside lock orientation, such as bolt-up, bolt-down, bolt-left, or bolt-right. The orientation may be communicated through the use of a switch or dial electrically connected to the inside electronics. This orientation information may then be used to synchronize the inner and outer electronics. The orientation information, however, would generally not be necessary in embodiments with generator detents and a common shaft, using reed switches for direction and position detection, for example.

With the generator configuration of the embodiments in FIGS. **2**-**4**, distinct positive and negative pulses are received as the magnetic ring **32***a*, **34***a* is rotated. Each detent around the dial **14** produces another of these pulses, either positive or negative. When the direction of the dial **14** is reversed, a pulse is generated with a polarity that is the same as the previous pulse. This allows the lock **30**, **60** to detect when a reversal in dial direction has occurred. However, with these pulses alone, the initial direction of the dial **14** cannot be determined.

To determine the initial direction and an index point for "0", this embodiment uses two Hall sensors **36***a*, **38**, **36***b*, **38***b*. In other embodiments, reed switches may be used as described above. The Hall sensors **36***a*, **38**, **36***b*, **38***b* are placed magnetically next to each other in such a way that the small magnet **40**, **42** passes under one, then the other Hall sensor. Direction may then be determined by the order in which signals are received by the Hall sensors **36***a*, **38**, **36***b*, **38***b*. This provides for both an index starting point and the direction of rotation. For embodiments using an LCD display with random number generation, only the direction information may be needed. However, if no communication is available because of a failure between the lock and the dial ring, or by design, synchronization may still be maintained between the internal electronics **44** and the external electronics **46** by knowing their common starting point.

Once the starting point and direction is known, a position counter may be incremented or decremented until the next dial reversal. With an LCD display, the incrementing or decrementing occurs from a random starting point as described above. At the time of the dial reversal, the last number is entered as the next combination number. Any practical amount of numbered sequences may be entered, but normally three numbers from 0-99 each are entered. With no LCD, and only a mechanical dial face, synchronization with the index position at "0" makes it possible to know where the dial is pointing.

In some embodiments, when the generator/transducer device is utilized as a position transducer alone, with no coils or iron, there are no voltage pulses to monitor. In this case two Hall sensors **36***a*, **38**, **36***b*, **38***b* are mounted facing the ring magnet **32***a*, **34***a* in such a way that they produce pulses that are approximately 90 degrees out of phase. From the way these pulses arrive, the direction and position of each increment can be detected. However, a starting point or "0" is still required. To detect the starting point, only one Hall element is mounted as normal about the small index magnet **40**, **42**. This method may also be utilized for the generator case above.

The power control and pulse shaping devices **80**, **82** may supply pulsed power directly to the internal and external electronics **44**, **46** respectively. In alternate embodiments, the power control and pulse shaping devices **80**, **82** may also charge internal capacitors **84**, **86** with the pulses of electricity generated from alternating magnets which are part of the ring magnets **32***a*, **34***a* in the generators **32**, **34** and electrical components **88**, **90**. The voltage of the capacitors **84**, **86** may then be supplied to the respective computers **48**, **50**. The computers **48**, **50** may be powered for a limited time from the capacitor voltage. Powered time of the computers **48**, **50** will be dependent upon the capacitance of the capacitor **84**, **86** and as well as the current drain of the computer **48**, **50**, the external electronics **46**, and the current drain of the display **18**. Similarly, the voltage and current resources required by a latch motor **92** in the internal electronics **44** will be a determining factor for the internal capacitor **84**. The size of the capacitor may be selected in coordination with the power requirements of the remainder of the system to provide power to the system for a fixed period of time, for example approximately 90 seconds, after the dial **14** and the generators **32**, **34** have ceased to rotate. The time period should provide adequate time to open the lock **30**, **60** or to pause in the entry of the combination without losing the previously entered elements of the combination. The time period may also be long enough to provide a significant delay in the reset of the lock electronics after the lock has become unopenable due to any of several conditions having occurred. This delay period may be a significant factor to defeat the use of a dialer for unauthorized entry into the secured enclosure. In some embodiments, the power requirements of the external electronics **46** may differ from the internal electronics **44**. In these cases, the capacitors **84** and **86** may be different and chosen to match the power requirements of each side of the lock **30**, **60**. However, requirements for some embodiments may include a synchronization of power-up detection to within the resolution of the index passage.

Computer **48** may also have an output to a latch motor **92** of the lock bolt retraction mechanism **94**, which acts to connect the latch **96** of the self-powered electronic lock **30**, **60** to the bolt retractor **98**. The latch **96** may be an arm, which when engaged with the bolt retractor **98**, may be pulled or pushed by the bolt retractor **980** when it is moved. The latch motor **92** may consist of a rotary actuator, or a rotary and lifting actuator, in the form of a small rotary mechanism for moving the latch **96**. The lock element **24** may be connected to the latch **96** and may be constrained by the internal housing **22**, as shown in FIG. **1**, to a sliding movement. The lock element **24** may be extended or retracted as necessary to lock or unlock the enclosure **100**, such as a safe, vault, room, etc.

Bolt retractor **98** may be engaged with the retractor drive **102** by a link **104**, as best seen in FIGS. **4** and **6**. The link **104** converts the movement of the retractor drive **102** and engaging point **106** into a linear movement of the bolt retractor **98**. The retractor drive **102** may be coupled to the shaft **20** such that rotation of the dial **14** provides the proper motion to the retractor drive after completing the entry of the combination code. In alternate embodiments, the latch motor or a similar motor may be employed to automatically move the bolt retractor **98** after successful entry of the combination code.

In an alternate embodiment of the self-powered electronic lock **110** and as best seen in FIGS. **5**, **6**, generators **112**, **114** are used to drive rotating encoder magnets **116**, **118**. Referring to the external electronics **120**, an electrical component **122** may be located under the external rotating encoder magnet **118** to provide rotational position information. A similar electric element **124** may be provided in the internal electronics **126** and similarly positioned with the internal rotating encoder magnet **116**. This type of element is reliable and relatively impervious to general dust, dirt, or humidity conditions. Other technologies in other embodiments such as piezo based or any other generator implementation may also be used to provide positional information.

In some embodiments, the dial **14** may serve multiple purposes. As described above in conjunction with the embodiments in FIGS. **2-4**, the dial **14** may be connected to the internal and external generators **112**, **114** through shaft **20** such that turning the dial causes the generators **112**, **114** to generate power. The dial may also serve to generate magnetic pulses used by the internal and external computers **128**, **130** that may be created through gears, which transfer the rotation of the shaft at the generators **112**, **114** to encoder magnets **116**, **118**. The internal and external generators **112**, **114** may be used to both generate power and generate pulses used by the internal and external computers **128**, **130**. Alternatively, the encoder magnets **116**, **118** may be directly coupled to the shaft **20** and may also act as rotors for the generators for power generation. The encoder magnets **116**, **118** may consist of a plurality of segmented magnetic members **128** having alternating polarity. The number of segmented magnetic members **128** on the encoder magnets **116**, **118** is not critical and may be selected to provide fewer field direction changes per revolution of the encoder magnets **116**, **118**. More field changes may easily be obtained by increasing the diameter of the systems, or by offsetting multiple magnetic rings. The magnetic fields of the segmented magnetic members may extend to and interact with internal and external electrical components **132**, **134**, such as coils, which are placed in proximity to the encoder magnets **116**, **118**, to generate pulses of electricity.

Prior implementations of the generators **112**,**114** have utilized an off the shelf stepper motor driven as a generator, which provides power and the ability to produce general rotational motion and direction information. Generators **112**, **114** used with an embodiment of the invention may be configured conceptually as one-half of a modified stepper motor with an additional indexing magnetic element. Each generator **112**, **114** may have slight detents at, for example, 50 positions (not shown). The generators **112**, **114** may be configured directly in coincidence for 50 detents, or in other embodiments may be mounted askew by one-half detent position to develop 100 detent positions around the dial. It is not intended that the generators **112**, **114** will require any gearing, although certain prior implementations of self-powered locks have utilized gearing. Use of gearing in the lock **110** would potentially add complexity, require additional space, and add additional cost. The additional detent configuration may be useful in certain embodiments of the self-powered electronic lock **110** as the additional detent positions may allow more rapid number advance for a given rotational angle. Previous implementations relied on speed of rotation instead of rotational position. In some embodiments, rate input may be implemented in lock **110**. In general, one detent will produce one number increment or decrement depending on the direction of rotation.

Encoders for embodiments having 100 detent positions around the dial should have a minimum of 100 increments per revolution to achieve the desired operation of 100 dial positions per revolution of the dial. In some embodiments, it may be desirable to be able to have some variability in the dial rotation input so that additional increments may be desired, e.g. 200 to 400. An embodiment with an encoder having 1000 or more increments per revolution would provide a minimum of five discernable positions on either side of the desired number location in general.

Any of the generally available rotational encoders are acceptable for use, such as the AS5040 manufactured and sold by Austria Micro Systems. The AS5040 utilizes a non-contact magnetic element, has low power requirements, and is small in diameter, which makes it well suited for this application. In addition, this hardware may be much more cost effective than equivalent optical implementations.

As the encoder magnets **116**, **118** are rotated by the dial **14** and shaft **20**, a series of absolute encoder readings may be obtained. The voltage and power generating pulses are fed to the respective power controls and pulse shaping devices **136**, **138** shown in FIG. **6**, which are both rectified for power and shaped and detected for incrementing and decrementing. The shaping of the pulses may be accomplished by circuitry that is conventional and forms no part of this invention. The pulses may then be fed to the respective computers **128**, **130**, such as microprocessor devices, over the phase lines **140-146** which may be interpreted a data pulses with direction change detection, sync, or index pulse with direction detection. The index pulses may be out of phase so they may be used to determine the direction of the rotation of the encoder magnets **116**, **118**.

The power control and pulse shaping devices **136**, **138** may supply pulsed power directly to the internal and external electronics **126**, **120**. In alternate embodiments, the power control and pulse shaping devices **136**, **138** may also charge internal capacitors **148**, **150** with the pulses of electricity generated from the encoder magnets **116**, **118** and electrical components **122**, **124**. The voltage of the capacitors **148**, **150** may be determined similar to the embodiments in FIGS. **2-4** described above.

External computer **130** as well as external computer **50** may provide outputs to the display **18**. The display may be capable of displaying numerals of at least two digits and arrows pointing in opposite directions. Symbols, such as arrows pointing in opposite directions, lightning bold for an error symbol, or a key symbol, may be used to indicate selection of the combination change mode as with previous electronic locks. LCD dot matrix displays may also be utilized to display the above information as well as additional status information in a more readable format. For example, the time of day and more readable reporting may be displayed in a ticker-tape fashion with backlit displays. Color displays may be desirable for some embodiments.

The display **18**, as described above, may be a Liquid Crystal Display or LCD device, which has an advantage of being a relatively low consumer of electrical power. Low power consumption may be a significant consideration because power generated by the rotation of the lock dial is relatively small and must be stored within the components of the electronics of the external power control and pulse shaping components **138** and **82** of the system.

As with the embodiments described above, computers **128**, **130** each have separate functions within the electronic lock **110**. The external computer **130** may display the combination number entry and may send this information to the display **18**. Additionally, the external computer **130** may send other indicators to the display **18**, such as those described above in conjunction with the display **18**. Internal computer **128** may also track the combination number entry, in some embodiments, simultaneously with the external computer **130**.

Computers **128**, **130** communicate through mechanical means such as that illustrated in the embodiment in FIGS. **5** and **6**. In this embodiment, computers **128**, **130** may communicate wirelessly through the mechanical rotations of the shaft **20**, which provide synchronized pulses through the encoder magnets **116**, **118** and electrical components **122**, **124** to each computer **128**, **130** respectively. Software resident in the computers **128**, **130** may transform the synchronized pulses into corresponding numbers between the computers **128**, **130**. The internal computer **128** may then perform checks of the entered combination numbers, as done in previous electronic locks, while the external computer **130** may display the numbers. This configuration requires no electrical conductors between the internal and external computers **128**, **130** or other internal and external electronics **126**, **120**. This configuration may allow for embodiments having an installation of the internal and external electronics **126**, **120** to be far off axis and/or mounted at greater distances, as long as they are mechanically linked. Bolt retractor mechanisms for this embodiment operate similar to those described with the embodiments in FIGS. **2**-**4** above.

The computers **48**, **50**, **128**, **130** may be any suitable microprocessors manufactured and sold on the market, such as the 80C51F manufactured and sold by Oki Electronic Industries Company, Ltd., of Tokyo, Japan, or one of several microcontrollers manufactured by Microchip incorporated in the U.S.A.

As with some prior electronic locks, and in the embodiments of the self-powered electronic lock **30**, **60**, **110** the lock combination code may be changed with the use of a change key **160**. If the current combination code of the lock has been entered correctly, the ports **162** of the internal computer **48**, **128** may be checked to see if the change key **160** has been inserted into the ports **162**. If the change key **162** has been inserted, a new combination code for the lock may be generated and confirmed. Because the combination for the lock is only stored in the internal computer **48**, **128** in the internal housing **22**, there may be no need to insert the change key **160** into the external computer **50**, **130** in the external housing **16**. In the embodiment shown in FIG. **3**, the wireless communications **64** may be used to indicate that the change key **160** has been inserted into the ports **162** on the display **18**.

In the embodiments described above, the dial **14** is utilized to enter the plurality of combination numbers that make up the combination code. In alternate embodiments, other devices may be utilized to enter the combination numbers, such as a keypad, magnetic card reader, or radio frequency ID card or tag. In still other embodiments, the lock may respond to biological characteristics recognized by biometric devices, such as a fingerprint or retinal scan, either in conjunction with a combination code, or exclusive of entry of a combination code or personal identification number (PIN). In these alternate embodiments, the dial **14** may still be utilized to generate power to the internal and external electronics **44**, **46**, **126**, **120** as well as be used to actuate the lock element **24**.

FIG. **7** shows an exemplary power up and dialing sequence of the self-powered electronic lock **30**, **60**, **110**. The process begins when the dial is rotated. The sequence between the internal and external electronics may be composed of similar steps, performed at similar times, which assists in maintaining a synchronization between the internal and external electronics. A delay may be imposed on the internal and external electronics as the dial rotation begins, for some embodiments, in order to charge the capacitor (blocks **202**, **232**). The delay may be prolonged if there is insufficient voltage to start the electronics (no branch of decision blocks **204**, **234**). If the voltage is sufficient to power the power-up electronics (yes branch of decision blocks **204**, **234**), the sensor is enabled (block **206**, **236**) to test for a complete index or sync pulse after the power is enabled to these components. After the sync or index location is indicated, the computers may be enabled. In some embodiments, after the index point, the microprocessor (CPU) will have time to power up and initialize itself. At this point in the power-up sequence, both CPUs will be powered up and waiting for the next sync, or index location. After detecting the passage of the index location, the next random number is displayed and internally examined at **218**, **248**. Both internal and external computers increment or decrement in unison until a dial reversal is detected. At this point the indicated number is stored in the internal computer and the next random number is calculated for display and internal calculation and comparison by the internal computer.

A random number may be generated as a starting point in both the internal and external computers based on a previous seeding value (blocks **214**, **244**). To keep the random number generation the same between the two computers, which may not be in electrical communication with each other, the same random number generation algorithm and seeding value may be used in both the internal and external computers. In some embodiments utilizing other wireless communications, the external computer may be the only computer that may need to generate random numbers as the alternate wireless communication methods may not require a synchronization of the internal and external electronics.

Seed values, in some embodiments, may be determined by a predefined table of seed values for resynchronization purposes. The seed value for the next random number may be the currently generated random number. In the event synchronization between the internal and external electronics is lost, one method for resynchronization may be to power up the lock by continuous dialing to the right. After the lock has been powered, a combination code of 00-00-00 could be entered. This would cause the lock to reseed the random number generator to the next seed number in the table, and also re-zero the transducers. The transducers may have to be re-zeroed due to mechanical wear, or due to the external dial ring, or dial misalignment, which may occur due to the physical movement of the components in relation to one another.

Entry of a combination number may be detected by the reversal of the dial and a continuing of the reversal motion for a predetermined number rotations. If the dial is reversed (yes branch of decision blocks **216**, **246**), then the random seed counter is incremented (blocks **218**, **248**) and the combination number is stored in the internal computer (block **220**). If the number is not the last number in the combination code (no branch of decision blocks **222**, **252**) the process continues at blocks **212**, **242**. If the number is the last number in the combination code (yes branch of decision blocks **222**, **252**), then the internal computer checks the combination code against the existing defined combination and operates as similar prior art locks, such as the electronic lock disclosed in U.S. Pat. No. 5,061,923 of Miller et al. Once a combination number has been entered, internal counters in both internal and external electronics are incremented and permanently stored. This counter may be used as a basis for the next random number displayed. In some embodiments, a modified random delay sequence may be implemented in which the last number input is the next starting number, and the randomness between dial rotation and display is accomplished through firmware located in both internal and external electronics. As described above, if no wireless communication is maintained, the external computer would detect the opening by an appropriate stall at the opening position of the dial. In the case of no wireless communication, this fact would not be used in the generation of the next displayed random number, only the fact that an acceptable number has been entered, no matter what the number was.

Detection of autodialer manipulation would be accomplished in the internal electronics. For example, if too many combinations are entered without opening, or combinations are entered too fast, the internal electronics would stop the checking for legitimate combination entry. The external electronics and computer could be made to determine that a legitimate combination had been entered in the case of non-wireless operation, but no bolt pulling sequences would ever occur. In this case, a real combination could have been dialed, but the internal computer would not detect it as legitimate, if autodialed, unless the combination was dialed in the first few dialing attempts. As continuing attempts to dial random combinations on power up are performed, delays would be built into prohibitively allow random combinations to be entered to the point that multiple entries of the correct combination must be entered to open the lock.

If the self-powered electronic lock experiences an intermittent failure of a component or a problem with a trace on a printed circuit board, causing a fault in the lock, the internal and external electronics may become unsynchronized. The self-powered electronic lock may be resynchronized to overcome the fault as shown in the flow diagram in FIG. **8**. If there is no fault (no branch of decision block **302**) then the lock continues to operate under normal conditions (block **304**). If there is a fault condition (yes branch of decision block **302**), the lock may be powered up with continuous dialing of the lock, for example, to the right (block **306**). Once powered up, the resynchronize by dial entry option is selected (block **308**), by for example, additionally dialing the combination 00-00-00. This option causes the internal random number generators in the internal and external computers to be reseeded with the next random number from an internal table (block **310**), thus resynchronizing the internal and external electronics. The lock then continues to operate under normal conditions (block **312**).

While the present invention has been illustrated by a description of various embodiments and while these embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

What is claimed is:

1. A self-powered electronic lock, comprising:

a housing;

a lock element mounted in the housing for movement relative to the housing between a locked position and an unlocked position;

a code input device operating with a first set of electronics;

an electric actuator operating with a second set of electronics, the electric actuator operatively coupled with the lock element to allow movement of the lock element from the locked position to the unlocked position;

a first electric power generator operative by a user to supply electrical power for operating the code input device and first set of electronics; and

a second electric power generator operative by the user to supply electrical power for operating the electric actuator and the second set of electronics,

wherein the first and second set of electronics are electrically isolated, and

wherein the first and second set of electronics are synchronized to generate a common number for a combination code.

2. The self-powered electronic lock of claim **1** further comprising:

a first battery electrically connected to the first set of electronics,

wherein the first battery provides power to the first set of electronics to supplement the electrical power supplied by the first electric power generator for starting lock operation.

3. The self-powered electronic lock of claim **1** further comprising:

a second battery electrically connected to the second set of electronics,

wherein the second battery provides power to the second set of electronics to supplement the electrical power supplied by the second electric power generator for starting lock operation.

4. The self-powered electronic lock of claim **1** further comprising:

a wireless communication device configure to allow wireless communication between the first and second sets of electronics to transmit non-combination information and to synchronize the first and second set of electronics.

5. The self-powered electronic lock of claim **1** wherein the first set of electronics is operable to display the common number and the second set of electronics is operable to check the common number against the combination code stored in the second set of electronics.

6. The self-powered electronic lock of claim **1** wherein the second electric power generator and the second set of electronics are located inside the housing.

7. The self-powered electronic lock of claim **6** wherein the housing further comprises an internal housing, and the self-powered electronic lock further comprises:

an external housing adapted to be accessible to the user of the self-powered electronic lock when the lock element is in the locked or unlocked position, wherein the internal housing and external housing are adapted to be disposed on opposite sides of an intervening structure.

8. The self-powered electronic lock of claim **7** wherein first electric power generator and the first set of electronics are located inside the external housing.

9. The self-powered electronic lock of claim 7 wherein the code input device is located proximate to or coupled with the external housing and accessible to the user.

10. The self-powered electronic lock of claim 1 wherein the code input device further comprises at least one of a dial, a keypad, a card reader, a radio frequency tag, a fingerprint scanner, a retinal scanner, or other biometric device.

11. The self-powered electronic lock of claim 1 further comprising:

a rotatable shaft; and

a dial coupled to the first electric power generator through the rotatable shaft, wherein rotating the dial transfers a rotational motion to the first electric power generator through the shaft to generate electrical power.

12. The self-powered electronic lock of claim 11 wherein the dial is additionally coupled to the second electric power generator through the rotatable shaft, and wherein rotating the dial transfers the rotational motion to the first and second electric power generators through the shaft to generate electrical power.

13. The self-powered electronic lock of claim 12 wherein the rotatable dial further operates as the code input device.

14. The self-powered electronic lock of claim 1 further comprising:

a display electrically coupled to the code input device and powered by the first electric power generator, the display operable to display code input by the user with the code input device.

15. The self-powered electronic lock of claim 14 wherein the display further comprises a liquid crystal display (LCD).

16. The self-powered electronic lock of claim 1 wherein the first and second electric power generators comprise a stepper motor.

17. The self-powered electronic lock of claim 1 wherein the first and second electric power generators comprise a ring magnet, a coil, and a Hall sensor.

18. A method of operating a self-powered electronic lock, wherein the self-powered electronic lock includes a lock element, an electric actuator, a code input device, first and second electric power generators, and first and second sets of electronics, the method comprising:

generating electrical power with the first electric power generator;

generating electrical power with the second electric power generator;

inputting a proper code into the code input device operating with the first set of electronics using the power generated by the first electric power generator and not using the power generated by the second electric generator;

simultaneously generating information in the second set of electronics synchronized with the first set of electronics, the information indicative of the proper code being entered into the code input device; and

using the power generated by the second electric power generator and not using the power generated by the first electrical generator, activating the electric actuator as a result of the information generated in the second set of electronics to thereby allow movement of the lock element from a locked position to an unlocked position.

19. The method of claim 18 wherein inputting the proper code further comprises at least one of:

rotating a dial, depressing a keypad, inserting a card into a card reader, reading a radio frequency tag, scanning a fingerprint, scanning a retina, or inputting other biometric information.

20. The method of claim 18 wherein the self-powered lock further includes a dial coupled to the first electric power generator through a rotatable shaft, and wherein generating electrical power comprises:

rotating the dial to transfer a rotational motion to the first electric power generator through the shaft to generate electrical power.

21. The method of claim 20 wherein the dial is also coupled to the second electric power generator through the rotatable shaft, and wherein generating electrical power comprises:

rotating the dial to transfer a rotational motion to the first and second electric power generators through the shaft to generate electrical power.

22. The method of claim 20 wherein inputting the proper code further comprises inputting the code by rotating the dial.

23. The method of claim 22 wherein the proper code comprises a series of numbers, and wherein the self-powered electronic lock further includes a display, powered by the first electric power generator, and wherein inputting the proper code comprises:

rotating the dial to a position corresponding to a first number in the series of numbers;

displaying the first number on the display corresponding to the rotation of the dial; and

reversing the rotation of the dial to input the first number in the series of numbers and indicate a start of an entry of a second number in the series of numbers.

24. The method of claim 21 wherein the first and second electric power generators comprise stepper motors configured to generate pulses of electrical power, and wherein simultaneously generating information comprises:

generating synchronized pulses of electrical power with the stepper motors by rotating the dial coupled to the shaft and the first and second power generators; and

simultaneously transforming the synchronized pulses of electrical power into corresponding numbers using the first and second sets of electronics.

25. The method of claim 21 wherein the first and second electric power generators comprise a ring magnet, a coil and a Hall sensor, and wherein simultaneously generating information comprises:

generating synchronized pulses of electrical power in the coil by rotating the dial coupled to the shaft thereby rotating the ring magnet;

determining a direction of the rotation of the dial with the Hall sensor; and

simultaneously transforming the synchronized pulses of electrical power into corresponding numbers using the first and second sets of electronics.

26. The method of claim 18 further comprising:

wirelessly communicating synchronization information and information not related to the proper code between the first and second sets of electronics,

wherein wirelessly communicating includes at least one of: communicating the information via Bluetooth technology, communicating the information via general radio frequency communications, communicating the information via pulsed magnetic fields, communicating the information via pulsed electric fields, or communicating the information via infrared signals.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,093,986 B2
APPLICATION NO. : 12/356324
DATED : January 10, 2012
INVENTOR(S) : Michael P. Harvey

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 12

Claim 1, line 22, change “set” to --sets--.

Claim 1, line 24, change “set” to --sets--.

Claim 4, line 47, change “set” to --sets--.

Signed and Sealed this
Sixth Day of March, 2012

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office